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ON THE FORMATION AND DEVELOPMENT OF A SUMMER STRATOSPHERIC ANTICYCLONE IN THE NORTHERN HEMISPHERE

[Following is a translatin of an article by I. G. Pchelko in Meteorologiya i Gidrologiya (Meteorology and Hydrology), No. 12, Moscow, 1959, pages 3-10.]

The problem of circulation in the stratosphere is one of the important meteorological problems subject to investigation according to the program of the International Geophysical Year.

Extension of the aerological network, a significant increase of the ceiling of atmospheric sounding and, finally, wide exchange of data between countries participating in the IGY, are substantially aiding the solution of the given problem.

We already have the first results of scientific investigations pertaining to such interesting problems as the structure of the baric and thermic fields in the stratosphere [3, 4], the wind regime and the interlatitudinal exchange of air masses at high altitudes [1, 2, 4]. Particularly, in Veksler's report at the Fifth Assembly of the Special Commission of the IGY, which was convened in Moscow in July-August 1958, AT_{10} maps compiled for the 15th of each month from July 1957 to July 1958 were demonstrated.

On the basis of an analysis of these maps, a general idea could be had about the evolution of the baric and thermic field at about 30 km altitude over North America, including also the American sector of the Arctic, as well as over the adjacent northern regions of the Pacific and Atlantic Oceans. The presence of an anticyclone over the polar regions during the period from May to August was also apparent on these maps.

The author has attempted in the present study to investigate more fully the evolution of a polar stratospheric anticyclone and in connection with that to investigate also the evolution of a baric field in moderate latitudes, encompassing the entire Northern Hemisphere.

This task was accomplished on the basis of an analysis of daily AT_{30} maps, performed by the author at the Central

Forecasting Institute experimentally in the perio from April to September 1958 to September 1958 and from April to July 1959. A series of AT_{25} maps, compiled from data taken from the daily statistical bulletin of the US Weather Bureau for the warm period of 1957 and 1958, were also analyzed for the same purpose.

Analysis of the AT_{30} maps was very difficult because of the lack of a sufficient amount of data from radiosounding the atmosphere, as well as and particularly because of the heterogeneity of their quality. Many errors were, obviously, connected with the warming up of the radiosonde under the influence of solar radiation.

Although, during the period of preparations for the IGY, systems of corrections for radiosonde readings were developed, it was unfortunately impossible to eliminate these errors. Most of the errors appeared in maps compiled from observations at 15 hours Moscow time. The errors moreover were confined mainly to stations located in the European territory of USSR south of the 69th parallel, where at that time soundings were performed at the time of the maximal position of the sun over the horizon. To characterize these errors, it is sufficient to point out that the average diurnal temperature change at the 30 mb surface level constituted 3.85° for these stations according to observations at 15 h. in July 1958, and the mean daily change of altitude of the given surface was 164.5 m. At the same time, for the 300 mb surface, where it would seem that the corresponding variations should be substantially greater, they were actually smaller, namely 3.14° and 84.6 m.

And, thus, it was necessary in analysis of the maps to use various comparisons between the data and to introduce different corrections. The absolute values of these corrections were most often equal to the mean diurnal changes of temperature and geopotential, which is pointed out in report [3] concerning the analysis of AT_{10} maps. Greatly helpful in the analysis were the data on wind which were generally of a better quality than the data on temperature and geopotential. Yet, even the wind data from some stations has often led to misunderstanding because of abrupt and unexplainable changes of its direction or velocity.

Notwithstanding these shortcomings, it was possible, because of systematic analysis, to discover general regularities in the development of atmospheric processes at the 24-26 km altitudes (having in view AT_{30} and AT_{25} maps).

We have established, following this development day after day, when and in which region the formation of a polar anticyclone as an independent form of circulation begins, how its strengthening, expansion in surface and trans-

formation into a circumpolar whirlwind occurs, and also, when and where its disintegration takes place.

In order to obtain generalized ideas about the development of processes in time and territory, aggregate AT_{30} maps were drawn up by decades. Circles characterizing anticyclonic or cyclonic fields in the given region were plotted on these maps, with an indication of the date (numerator) and of the geopotential value (denominator). An anticyclonic field was denoted by a light circle, sometimes with an arrow (eminence); a cyclonic field by a black circle, sometimes with an arrow (depression). In many cases, however, particularly in midsummer, when we actually dealt with one anticyclone over the pole, in other places points were simply plotted with an indication of the most characteristic values of the geopotential.

On each of these maps, smoothed out structure contours were drawn, accounting for the averaged geopotential values at the plotted points. These lines then served as demarcation lines between cyclonic and anticyclonic regions. These lines, moreover, more clearly determine the configuration of one or another form of circulation.

The aggregate maps compiled in such a manner can be considered in a certain way to be identical with the mean decade AT_{30} maps. Such maps were compiled for the period from May to August 1958 (on maps accompanying this article, the number of points has been indicated in a decreased quantity).

As a result of analysis of the daily and the aggregate AT_{30} maps, it was possible to reach the following conclusions about the evolution of the baric field at the 24-25 km altitudes over the Northern Hemisphere during the warm period of 1958.

1. The development of the polar anticyclone as an independent baric formation began around 10 May over the American sector of the Arctic regions. The center of the anticyclone with a maximal value of the 30 mb altitude surface of about 2410 dkm was located on 10 May over the western regions of the Canadian archipelago. In the European-Asiatic sector of the Arctic regions, including continental regions up to 55° N. latitude and over Eastern Siberia to 45° N. latitude, cyclonic formations predominated at this time.

The polar anticyclone later became stronger, and spread over a large surface. As the aggregate AT_{30} map for the period from 19 May to 27 May (Fig. 1) demonstrates, the entire polar region as well as the northern regions of the Eurasian continent up to approximately 65° latitude and

northern regions of the American continent up to approximately 55° latitude were during this period under the influence of antycyclonic circulation. The center of the polar anticyclone migrated at this time to the region of Canadian archipelago. The mean decade value of the 30 mb altitude surface constituted about 2438 dkm.

The moderate latitudes of the hemisphere were, in the given period, under the influence of cyclonic regions with a minimal geopotential value of about 2,392 dkm, which were displaced from west to east. Over the Eurasian continent, the region occupied by cyclones was located predominantly between the 65 and 45° latitudes, and over the American continent approximately between the 55 and 40° latitudes.

More southward, approximately between the latitudes 45 and 30°, there was located a second anticyclonic region with a maximal geopotential value of about 2,420 dkm over the territory of the ChPR (Chinese People's Republic) and of about 2,435 dkm in the region of the Azores.

South of the 30th parallel, there was observed a transfer into the equatorial zone of lowered pressure with a value of the 30 mb altitude surface, for instance in the region of the Philippines, of about 2,384 dkm.

2. With the strengthening of the polar anticyclone, its central part was displaced from the Canadian archipelago to the pole. Simultaneously, the influence of this anticyclone spread to the moderate latitudes, while the previously existing cyclonic circulation gradually attenuated.

Towar the middle of June, the polaranticyclone seemed to merge with the subtropical high-pressure zone; with the presence of an equatorial depression, which was even somewhat extended northward, the horizontal geopotential gradient over the entire hemisphere was almost uniformly directed from north to south. That is, as the aggregate map for the second decade of June (Fig. 2) shows, a homogeneous anticyclonic field of circulation in the form of a circumpolar whirlwind, with the general movement of atmosphere from east to west, was established. The mean geopotential value over the pole for the second decade constituted about 2,463 dkm. It is important to note that the configuration of the structure contours in June often had a wave-like character with a large wavelength, which was manifested particularly in the presence in various regions of spurs of the polar anticyclone. Consequently, the winds in moderate latitudes in June were predominantly of northeasterly and southeasterly directions.

3. The stratospheric anticyclone reached its maximal development in the third decade of July (Fig. 3), when

the mean decade value of the geopotential in the center of the anticyclone over the pole constituted about 2,474 dkm. Unlike the preceeding month, in July the configuration of structure contours had a more homogenous, latitudinal character; consequently, the winds in the moderate latitudes also had a more strictly easterly direction.

4. Beginning from 22 July, when the absolute value of the geopotential in the polar region reached 2,486 dkm., the anticyclone gradually began to loose strength. However, already in the course of the month, that is before the beginning of the third August decade, the anticyclone continued to exist as an independent baric formaion with a center close to the pole and only in the course of the third decade of August did a substantial transformation of the AT_{30} field take place. As the aggregate AT_{30} map for this decade shows (Fig. 4), cyclonic formations began to appear over the polar region in the direction over the Canadian archipelago. The median value of the altitude of the 30 mb level over the pole constituted about 2,414 dkm. The anticyclonic region, however, began to occupy only moderate latitudes. The axis of this anticyclonic system passed over the American continent and over the Atlantic region approximately along the 50th parallel, over Europe around the 55° latitude, and over the Asiatic continent, approximately along the 60° latitude.

Such are the special features of the evolution of the summer stratospheric anticyclone in 1958, which in their basic aspects also manifested themselves in 1959.

In Fig. 5 are shown the changes of altitudes of the 30mb surface over the polar region during the period from April to August 1958 and from April to July 1959. Besides, for 1958 there were taken mean decade data, and, for 1959 extrapolated data every five days. Both curves show that from April to the day of the summer solstice (22 June), a fairly rapid elevation of the isobaric surface takes place.

This can be explained first of all by the progressive warming up of the stratospheric air as a result of absorption of the ultraviolet solar radiation by ozone. During the next month, the isobaric surface is approximately on the same level and then rapid lowering sets in. It is interesting to note that the beginning of the formation of polar anticyclone in spring (April, May), as well as its disappearance toward the end of August, falls at a time when the geopotential of the 30 mb level in the polar region reaches 2,400-2,420 dkm.

Changes of altitudes of the 25 mb level over polar region for the July-August 1957 and the April-August 1958 periods are also shown in the same figure. These curves

are absolutely identical with the first curves, which fact indicates complete correspondence of the anticyclogenetic process at the 30 and 25 mb levels of surface.

The problem arises whether the above-stated special features of evolution of the baric field in the stratosphere are typical for the warm season of each year, or whether in different years there may be substantial deviations from these features?

It is difficult to answer this question at the present time if only because of the insufficient quantity and unsatisfactory quality of basic data for high altitudes; we cannot vouch for the correctness of the analysis of the development of atmospheric processes at these altitudes in all its details. On daily analysis of AT_{30} maps, for instance, we often encounter the factor that, against the general background of increasing anticyclonic circulation over limited regions, traits of cyclonic circulation originated. The latter were apparent either in the changes of wind direction or in significant changes of altitudes of the isobaric surface. Yet, because these changes were contradictory, great doubts were entertained as to the justice of disturbing the established anticyclonic circulation. On the other hand, these factors could not be left out of consideration, inasmuch as they originated during certain processes in the troposphere. In the majority of cases, the disturbances in moderate latitudes originated upon the invasion of cold air in the troposphere and, in connection with this, at the time of a deepening of the depression. These small cyclonic disturbances therefore were also not marked by us on the aggregate maps. This can be seen, for instance, on the map for the third decade of July (Fig. 3), in which the disturbance of anticyclonic circulation over the southern regions of the European territory of USSR is shown.

Although upon analysis of AT_{25} maps compiled from the data of the daily statistical bulletin of the US Weather Bureau we did not encounter similar disturbances, the problem of determining to what altitudes of the stratosphere the influence of tropospheric disturbances reaches requires a thorough investigation.

In connection with this, a comparison of some results of study of AT_{30} maps for 1958 and 1959, analyzed by the author for the same period, is well worth attention. The investigation of the curves of the variation of altitudes of the 30 mb surface over polar region (Fig. 5) discloses a substantial difference in absolute values of the altitudes during the period from 10 April to 20 May of the given years.

During 1959, the altitudes of the 30 mb surface were significantly greater than during the same days in 1958, particularly in April. Evidently, some supplementary factors were active in the spring of 1959 which facilitated more active warming up of air in the stratosphere and, in connection with this, the elevation of the 30 mb surface.

This was manifested also in the fact that the formation of the polar stratospheric anticyclone in 1959 occurred between 10 and 15 April, that is, almost one month earlier than in 1958 (10 May). Having originated as well as in 1958 over the American sector of the Artic region, this anticyclone spread to the territory of Europe considerably earlier than in the preceeding year.

Let us note in passing that April 1959 in Eastern Siberia, in contrast to April 1958, was characterized by the protracted existence of a widespread stable depression at the level investigated.

All of this points to the fact that the structure of the baric field at high altitudes during the same seasons can be different in different years. This problem should be a subject of further investigations.

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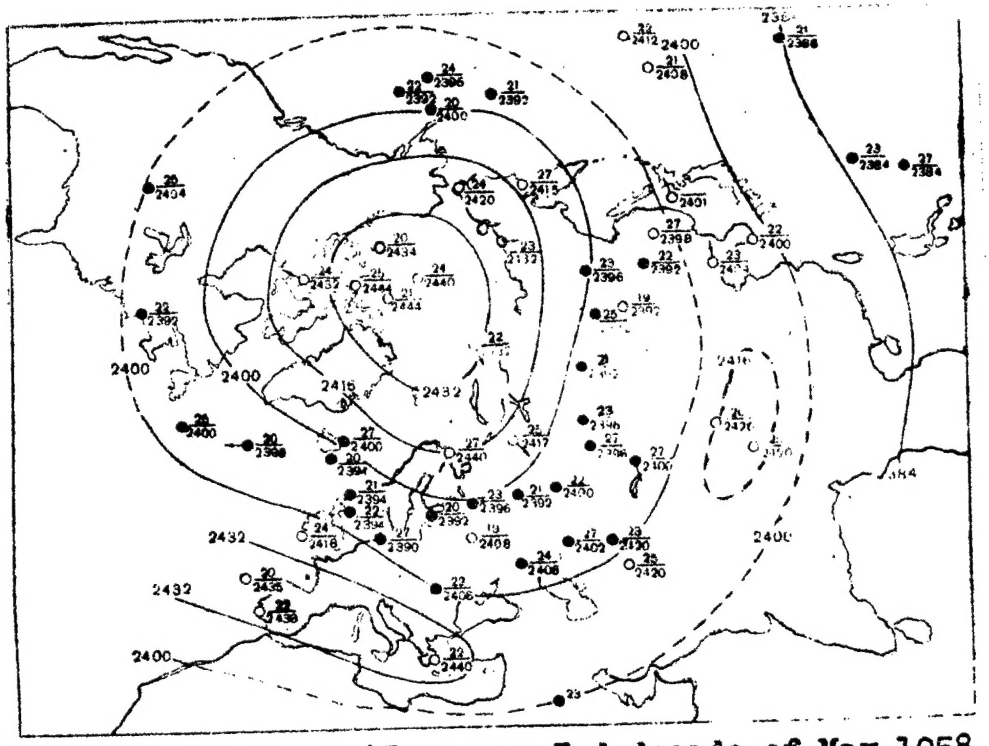

Fig. 1. Aggregate AT_{30} map, 3rd decade of May 1958.

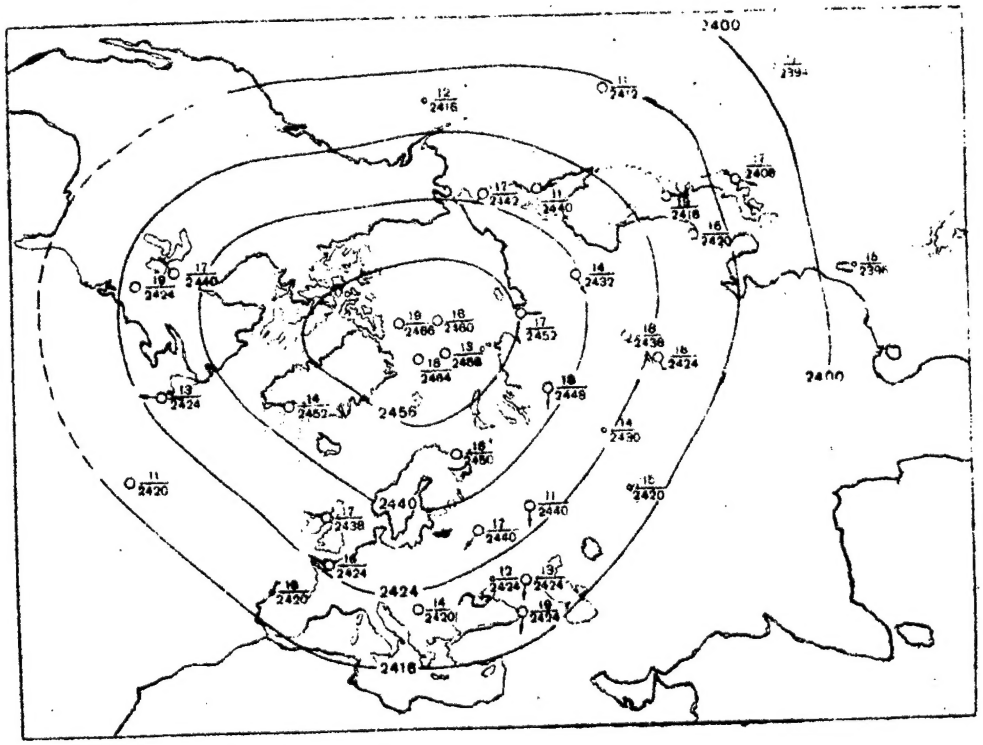

Fig. 2. Aggregate AT_{30} map, 2nd decade of June 1958.

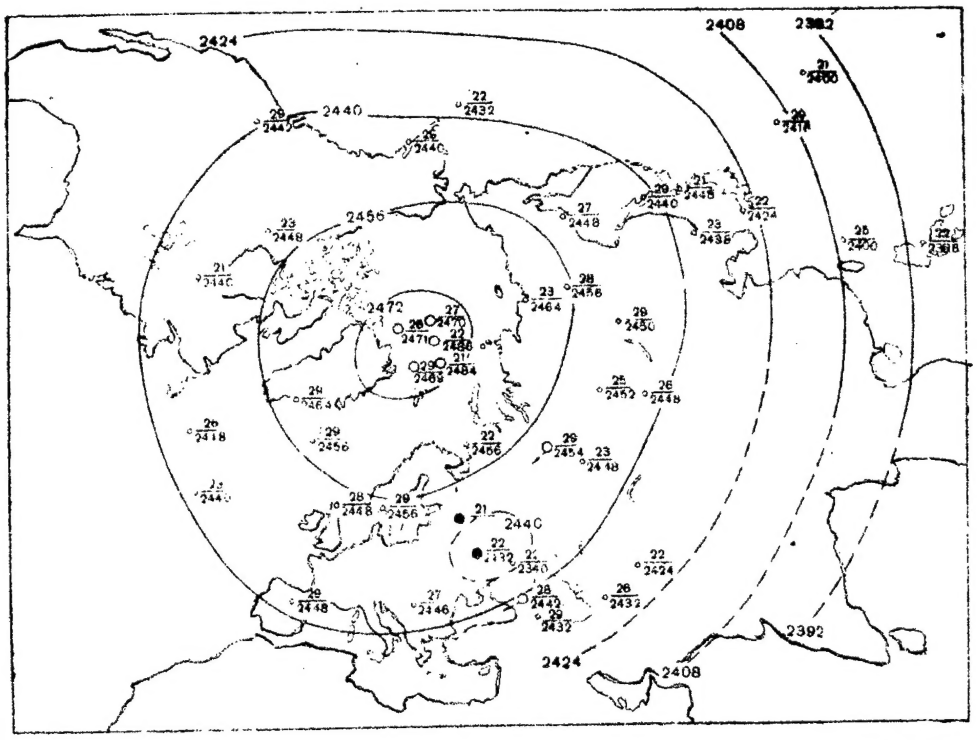

Fig. 3. Aggregate AT_{30} map, 3rd decade of July 1958.

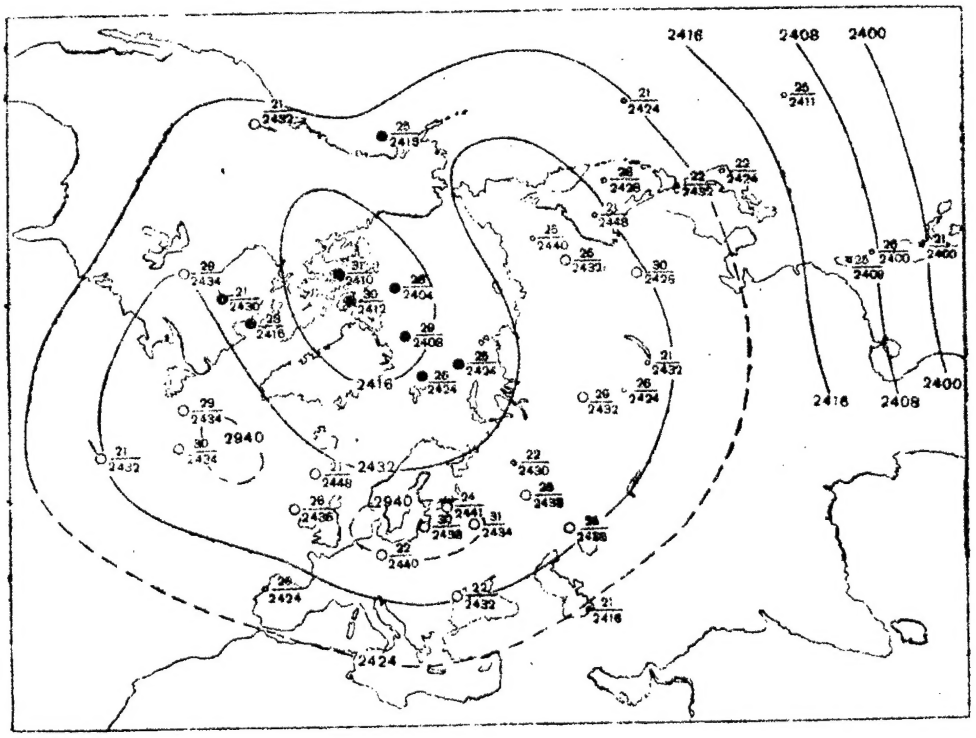

Fig. 4. Aggregate AT_{30} map, 3rd decade of August 1958.

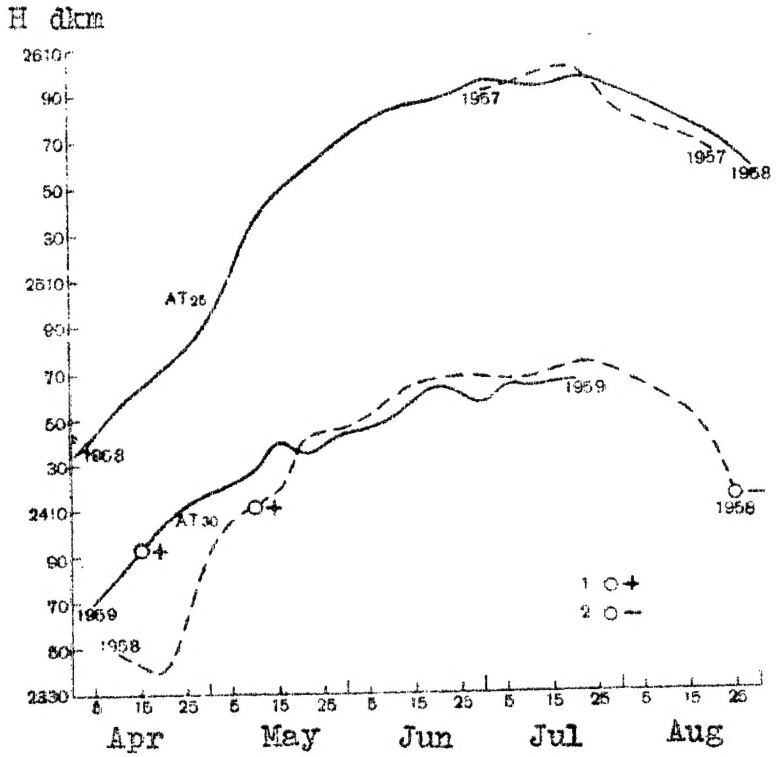

Fig. 5. Change of altitudes of 30 and 25 mb surfaces over the northern polar region.

1) beginning of anticyclone formation;
2) dissolution of the anticyclone.

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